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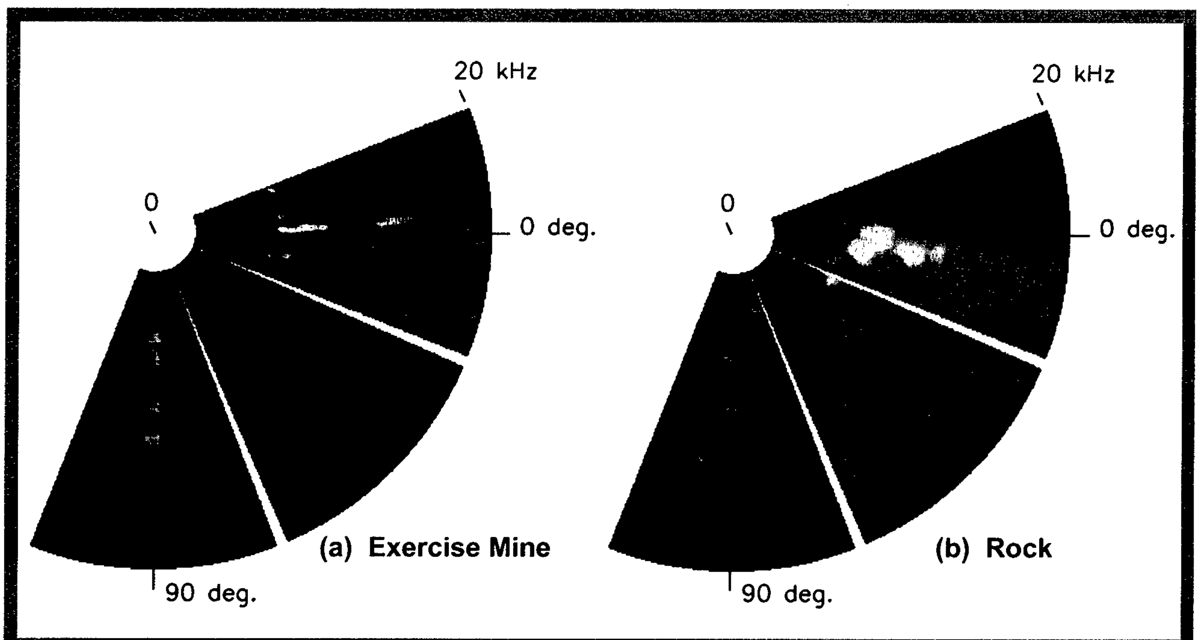

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SACLANTCEN SR-324

PROUD TARGET CLASSIFICATION BASED ON MULTIPLE ASPECT LOW FREQUENCY RESPONSE

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Jan L. Spoelstra
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Executive Summary:

The decision to classify a detected mine-like echo (MILEC) as a mine-like contact (MILCO) requires time consuming close range inspection. The result of this inspection is the identification of the object as a mine or as a non-mine, mine-like bottom-object (NOMBO). Enhancing the classification process decreases the duration of a mine hunting operation by reducing the proportion of NOMBO's in MILCO's. The classification process is a detailed analysis of the acoustic response in order to identify elements which allow discrimination between mines and NOMBO's. As MILCO's may be natural (rock outcrops, coral reefs) or man-made objects, the analysis of the external shape of the object (acquired by conventional high frequency MCM sonars) is complemented with the analysis of the internal structural properties (shell, inner material) obtained at lower frequencies. This approach allows discrimination between objects of similar external shapes with different internal properties.

This report demonstrates the potential of applying low frequency acoustics (2-20 kHz) to proud mine classification. A classification methodology using the aspect variation of the target response has been defined. The method, which performed well on objects in the water column was tested on experimental data from objects lying on the seabed. The method operates first in the time (space) domain to reconstruct the external shape of the object, from which a preliminary classification is made. When the object is similar to a mine, in terms of shape and dimensions, a more accurate analysis is performed in the frequency domain using the aspect variation of the target response. As low frequency penetrates the object, the echo contains information on the internal properties of the object. This is of particular interest for objects having similar external shapes but different internal properties.

To assess the potential of the method, an experiment was conducted in Marciana Marina (Island of Elba, Italy) in October 1998. The low frequency acoustic signature was acquired using a parametric sonar (2-20 kHz secondary frequency band). The reconstructed object shapes (spatial processing) shows clear discrimination between an exercise mine and rocks. Based on these results, the exercise mine is selected for further analysis in the aspect-frequency domain. This analysis shows that the object's shape is close to a cylinder and has a non-metallic shell.

The experimental devices also allow acquisition of the high frequency images of the objects with a 325 kHz interferometric sonar. These data offer the opportunity to test the latest version of automatic target recognition algorithms on multiple aspect object shadows. The results show that the combination of 3 aspects (0°, $45^\circ$and 90°) allows clear discrimination between the exercise mine and the rock and, conversely, that for particular orientations of the objects, a single view is not sufficient to differentiate between the mine and the rock.

The classification results obtained using two different frequencies (8 kHz and 325 kHz) demonstrate that fusing the information from low frequency echoes and high frequency shadows ensures better classification of mines.

Future work will be dedicated to the validation of the results presented here on more complex cases (different bottom type, different targets, different burial depth) through modelling and at-sea experiments.

PROUD TARGET CLASSIFICATION BASED ON MULTIPLE ASPECT LOW FREQUENCY RESPONSE

B. Zerr, A. Tesei, A. Maguer, B. Houston and P.A. Sletner

Abstract:

The aspect dependence of the acoustic signature has been demonstrated to be an essential indicator to discriminate between man made and natural underwater objects. A classification method has been defined using the variation with incidence angle of the acoustic waves scattered by an elastic object. As the experiment conducted in a basin on free field cylinders produced encouraging results [1, 2], more realistic acoustic measurements were conducted on natural and manufactured objects positioned on the seabed. The external shape, extracted from a reflection map reconstructed by tomography, allows selection of candidate objects for detailed analysis of their scattering properties. The resonance scattering analysis, limited to selected aspects in its original version (e.g. broadside for a cylindrical shape) has been extended to incorporate aspect varying features. The variation with incidence of the acoustic wave diffracted by object discontinuities has also been introduced. This report presents and discusses the results from the SACLANTCEN-NRL TASCOE (TArget Scattering in COntrolled Environment) experiment conducted in water depth of 15 m at Marciana Marina (Elba, Italy) in October 1998 [3]. The scope of the TASCOE experiment was to acquire the acoustic response of proud objects over a broad range of azimuth angles. The data analysis shows that the aspect dependence of the acoustic waves scattered by elastic objects (ka = 2-20) allows clear discrimination between manufactured and natural objects. To provide elements of comparison with more conventional techniques, a multiple aspect automatic classification algorithm has been applied to the high frequency (325 kHz) images of the same objects.

Keywords: Sea Mine Classification ∘ Automatic Target Classification ∘ Resonance Scattering Analysis ∘ Computerized Tomography

Contents

1
Introduction

The discrimination between man-made and natural underwater objects is a challenging goal for mine hunting and post-conflict area mine clearing. The current approach to solve this problem is to image the seabed with high-frequency high-resolution sonars. The discrimination between man-made and natural objects is based on the analysis of the geometrical properties of the object acoustic shadow projected on the seabed. This technique performs well on simple seabeds and its performance can be improved by fusing the information from multiple aspects [4]. At such high frequencies, the predominant effect in the echo structure is the specular reflection from the outer shape of the object. As the acoustic shadow already gives information about the object shape, the introduction of the high-frequency echo in the classification process leads to limited performance improvement. To acquire more information on the internal and external structure of the object, the low-frequency properties (2-20 kHz) of the echo were investigated.

A methodology for classification between man-made and natural targets [1, 2] was proposed based on aspect-dependent analysis in the time domain. Estimation of geometrical and elastic target parameters was included in the case of cylindrical shapes by single-aspect (broadside) resonance analysis. The target response in time and frequency domains versus aspect is analyzed in terms of reflection/diffraction features. These features can be processed, for example, by computerized tomography in time and by multi-aspect scattering analysis in frequency. The analysis allows the extraction of information on external shape and size to provide the preliminary classification as natural or man-made. When the identification of a man-made target is addressed and the target can be assumed as elastic, an approach based on mono-aspect or multi-aspect resonance scattering analysis can be applied. This processing phase is aided by the inversion hints provided by the preliminary classification process in terms of shape and approximate size. It consists of extracting and processing the features from the elastic phenomena generated by the target structure. This information may be able to provide additional target characterization in terms of geometrical and elastic parameter estimates (e.g., more accurate dimension estimates, shell material and thickness, inner medium properties). This low frequency approach could allow discrimination between objects of the same external shape but with different internal characteristics. In this work the approach is extended to multiple aspect frequency analysis of either rigid or elastic scattering features and tested on experimental data, collected at sea on proud objects during the TASCOE

(TArget Scattering in COntrolled Environment) experiment (Elba Island, Italy, October 1998). The aim of the experiment was to acquire the variation with azimuth of the target response at low (8 kHz ricker pulse) and high (325 kHz) frequency. The low and high frequency target responses complement each other to provide better characterization of mine-like objects. This complementarity is described in section 3 (multiple aspect shadow) and in sections 4 and 5 (low-frequency multiple aspect echo).

2
Description of the experiment

To address, in situ, the capability of discriminating between man-made and natural objects, the TASCOE experiment was conducted in October 1998 off Marciana Marina (the island of Elba, Italy). The collaborative experiment between SACLANTCEN and the Naval Research Laboratory (NRL) aimed to acquire, in real conditions, the aspect dependence of the low-frequency acoustic field scattered by objects, previously measured with high positioning accuracy in the calibrated environment of the NRL tank.

The main experimental device is the SACLANTCEN underwater rail [5]. The location of the target is a trade-off between a wide azimuth angle variation (if the target is close to the sonar) and a low grazing angle variation (obtained when the target is far from the sonar). Considering that the effective length of the rail is 20 m, the target is placed at a horizontal distance of 20 m from the center of the rail to provide 45° of azimuth angle variation. The sonar is mounted 6 m above the seabed, which keeps the variation of grazing angle below 2°. The objects are rotated by divers by steps of 45° to cover a wider range of aspects. The clear water of Elba is a key element to achieve precise rotation and positioning of the objects.

Figure 1 shows a block diagram of the data acquisition. The sensors are mounted on a frame, equipped with pan and tilt devices, mounted on a 5 m tower. The low frequency source is 8 kHz produced by a parametric sonar [6]. The receiver is a 16 element vertical array. The low frequency data are filtered and sampled at 100 kHz on a HP VME workstation. The high frequency sonar is built using elements of a 325 kHz commercial sidescan sonar [7]. The transducers are placed on top of each other to allow interferometric processing. The received data are shifted to base band and sampled at 24 kHz on a 8 channel DAT recorder. The actual inclination and orientation of the sensor frame are monitored by a motion reference unit. All the recorded data are time stamped. The data acquisition is remotely controlled from the shore laboratory. The shore laboratory also hosts computers for data quality check and near-real-time data processing. This facility allows to reconstruct the precise bathymetry from the high frequency interferometric data. The high frequency sonar image and the bathymetry of the site are shown in Figs. 2 and 3, respectively. The bathymetry has been corrected from platform movements using the data from the motion reference unit. The image and bathymetry can be combined in a 3D representation of the experimental site (Fig. 4). The 3D representation is built by

computing a triangular mesh from the bathymetric data (Fig. 3) and mapping the sonar image (Fig. 2) as a texture. As it can be observed in Fig. 4 from the gray horizontal stripe, the estimated along-track and across-track slopes are 3° and 4°, respectively. The use of estimated slopes instead of flat seabed approximation ensures a more precise pointing of the source to the target. The mono-static acoustic signature in the 2-20 kHz frequency band has been measured for an exercise mine and two rocks. The exercise mine has a fiber-glass shell with a roughly cylindrical shape truncated at one end. The first rock is from NRL and its acoustic signature has been precisely measured in the water tank before being placed on the seabed. The second rock is the SACLANTCEN "Val Di Pino" rock which has been used as natural object in all experiments related to Project 031-2 "Temporal classification". For each target, the aspect variation in azimuth of the acoustic signature has been measured in successive steps of 45°. For each step, the target is precisely positioned and oriented by the divers. The acquisition is performed by moving the tower along the rail to have an angular sampling of 1° in azimuth. The displacement of the tower from one acquisition location to the other takes approximately 8 minutes, making a total of approximately 6 hours for a 45° acquisition step. As only two 45° steps can be acquired per day, the range of azimuth angle acquired per target has been limited to 180°. Figure 5 shows the aspects which have been acquired for the exercise mine and the rocks. Figures 6 to 8 show the time versus aspect and frequency versus aspect representation of the scattered sound for the rocks and the exercise mine. Figure 9 demonstrates, in the frequency versus aspect domain, the differences of mono-static back-scattering between the exercise mine and a rock.

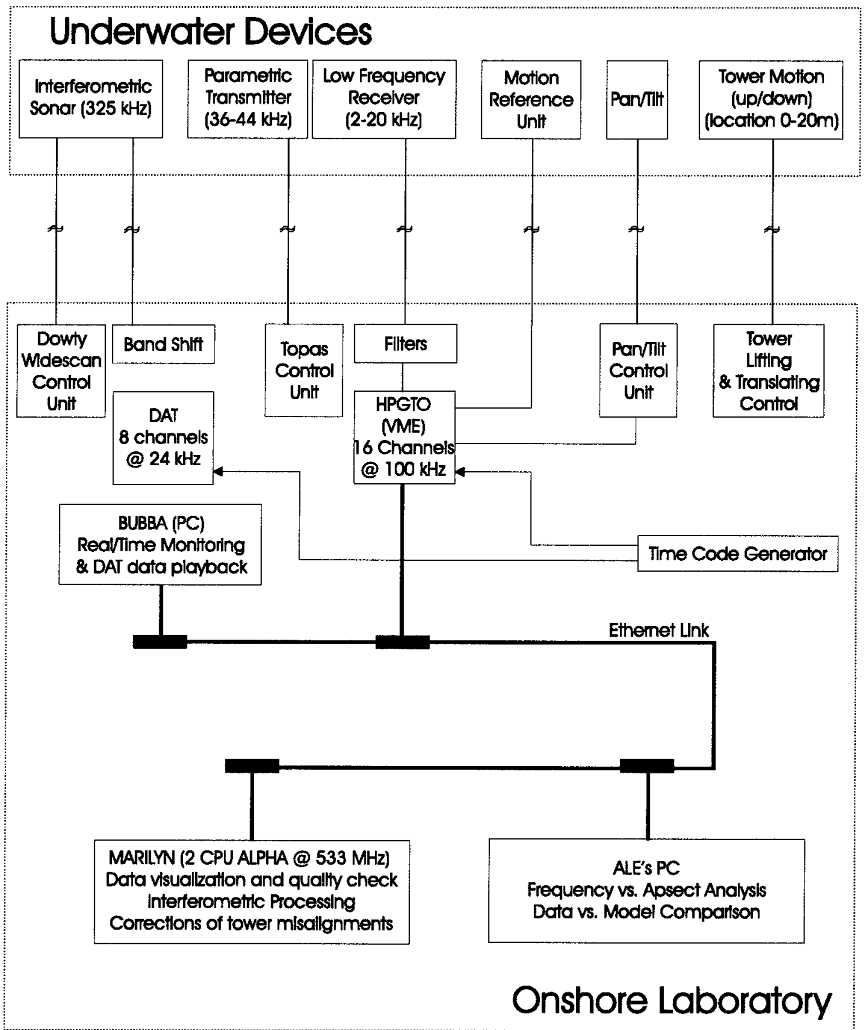

Figure 1 *Data Acquisition.*

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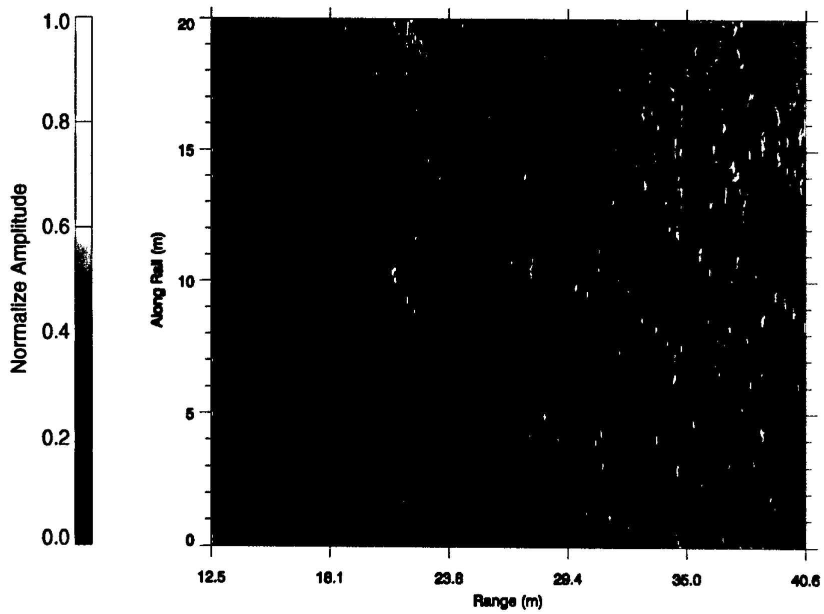

Figure 2 *High frequency sonar image of the experimental site.*

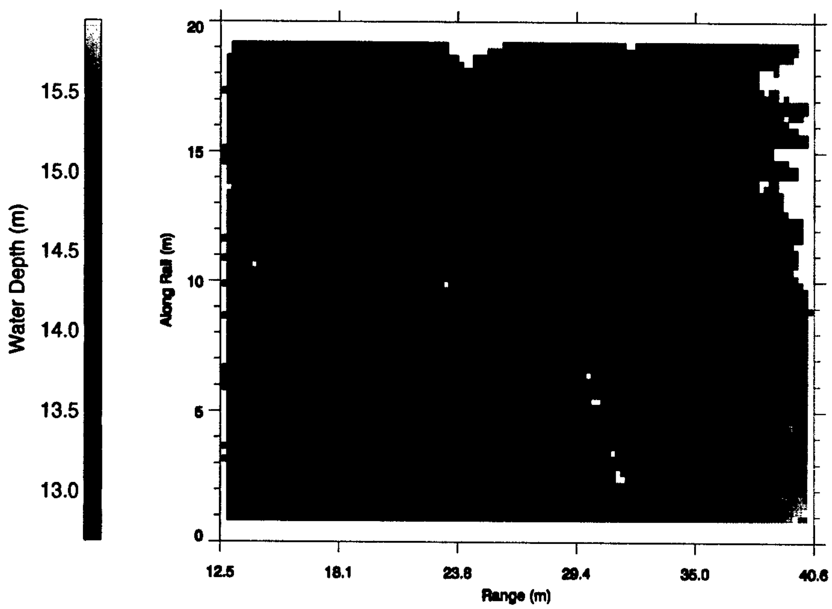

Figure 3 *Precise bathymetry of the experimental site from interferometric sonar processing.*

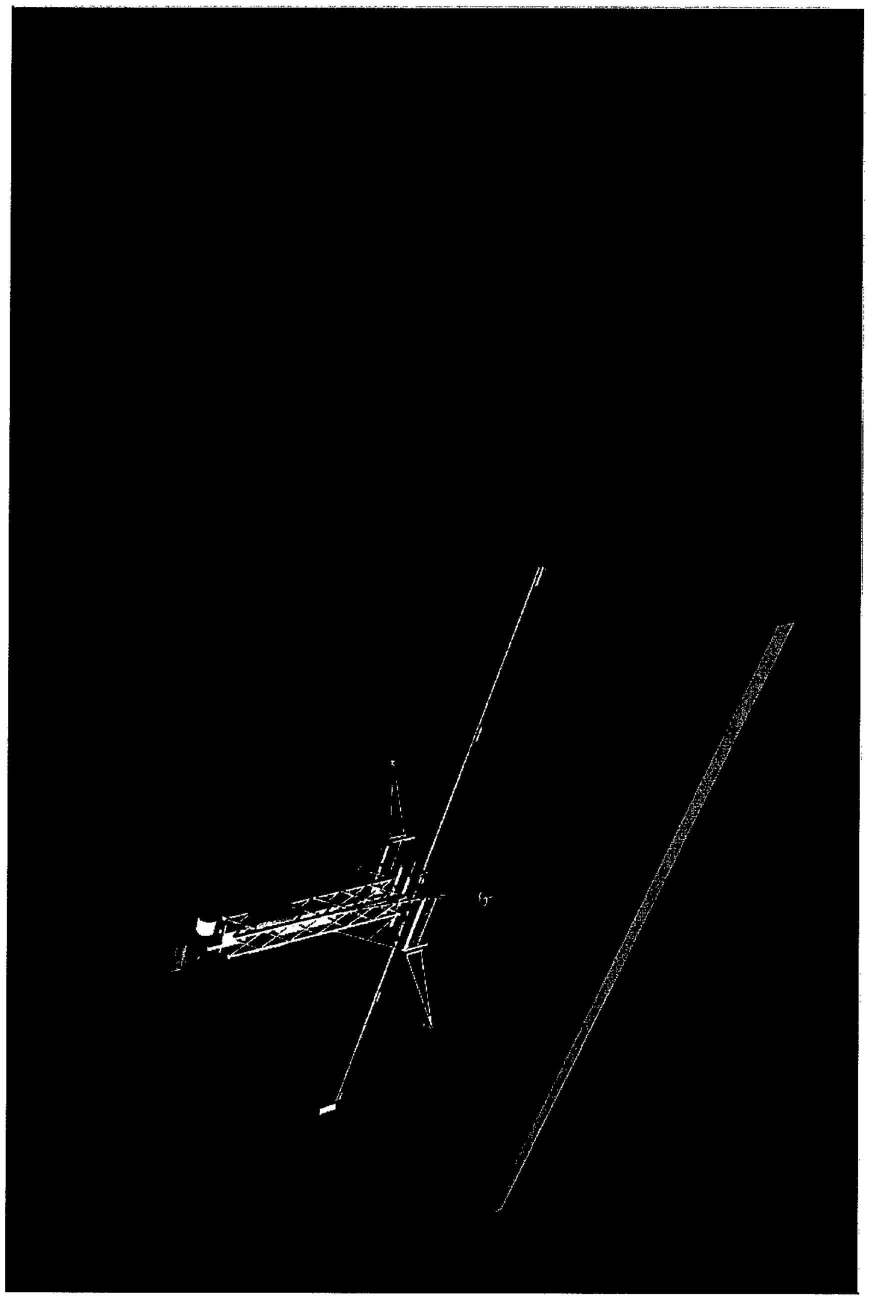

Figure 4 *3D reconstruction of the experimental site, using image and bathymetry from the intereferometric sonar.*

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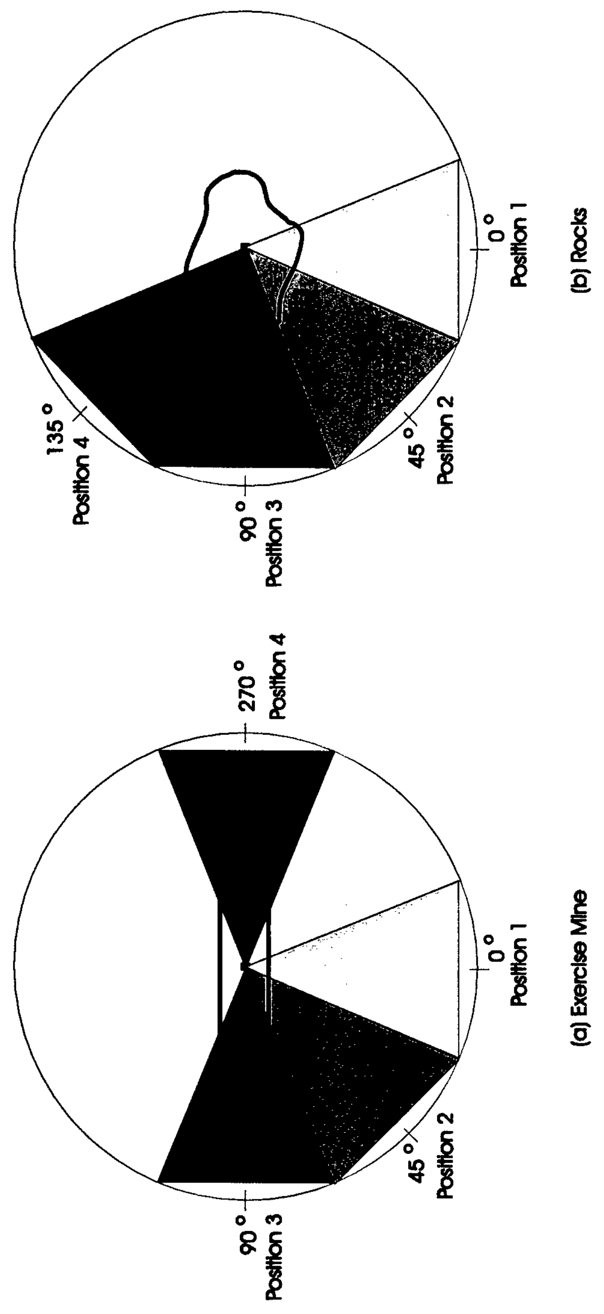

Figure 5 *Aspect selection for exercise mine and rock.*

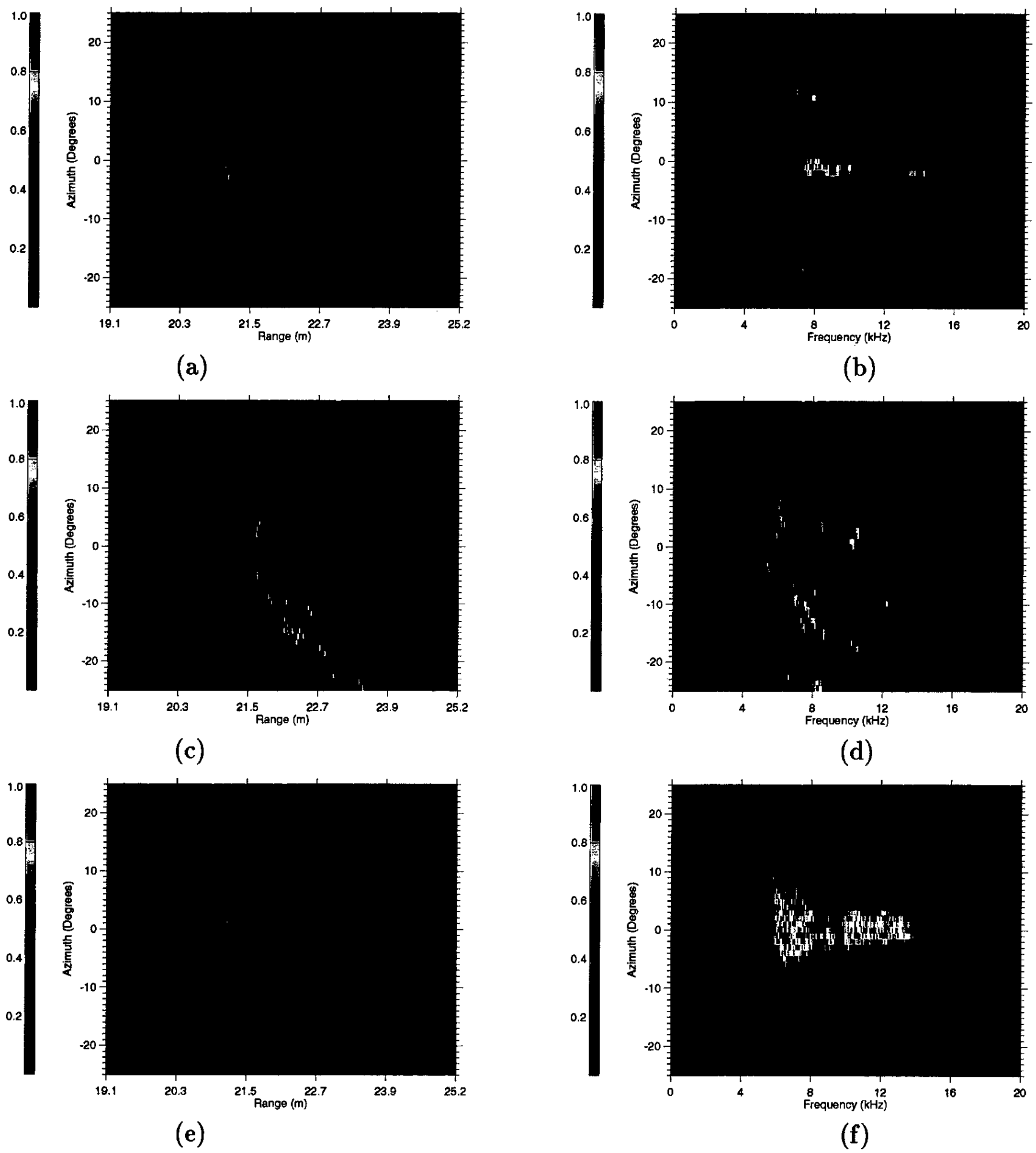

Figure 6 *Aspect variation of the scattered sound for the exercise mine. In each plot, the amplitude is normalized to the maximum. (a) Time vs. aspect at 0° . (b) Frequency vs. aspect at 0° . (c) Time vs. aspect at 45° . (d) Frequency vs. aspect at 45° . (e) Time vs. aspect at 90° . (f) Frequency vs. aspect at 90° .*

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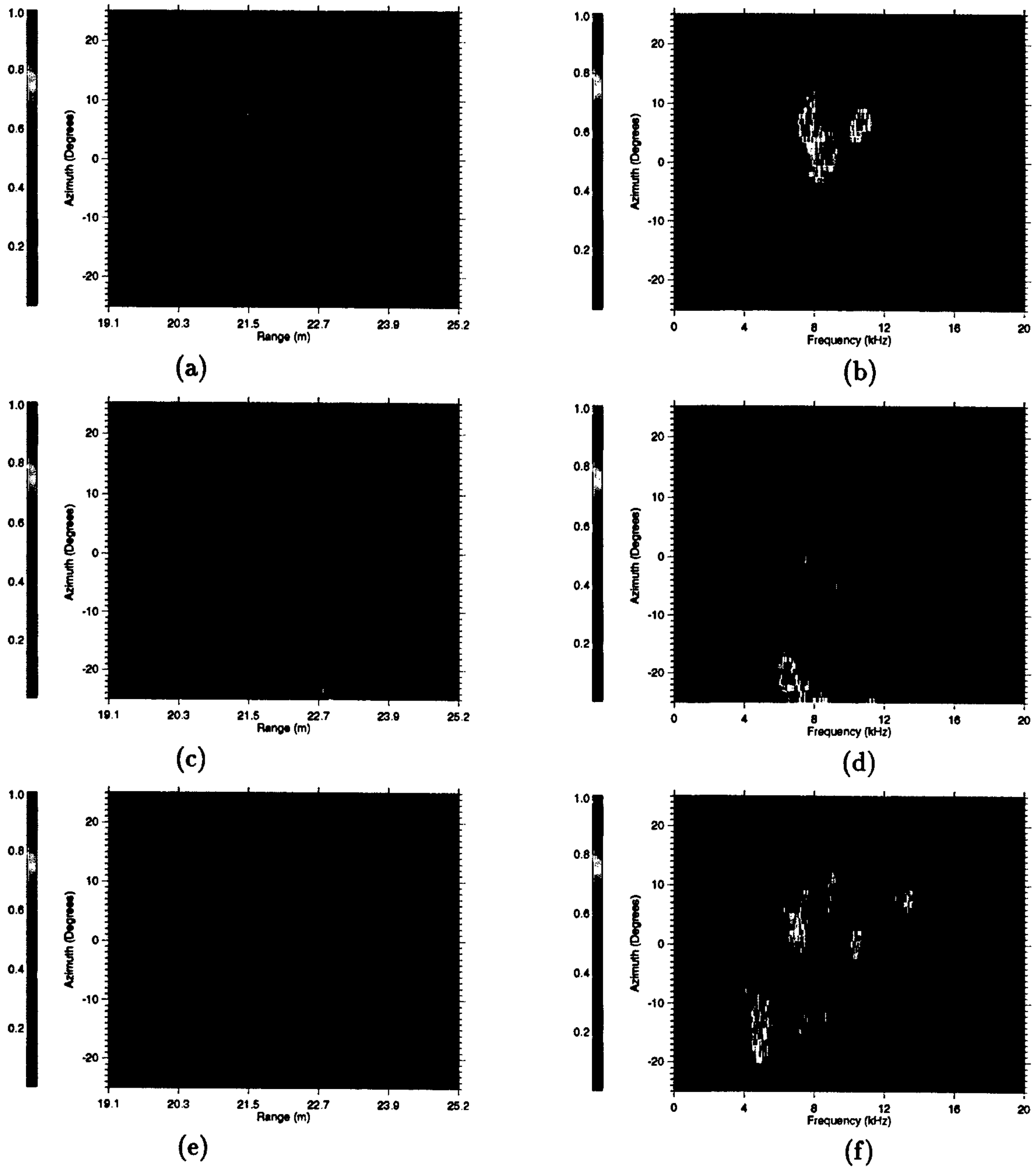

Figure 7 *Aspect variation of the scattered sound for the NRL rock. In each plot, the amplitude is normalized to the maximum. (a) Time vs. aspect at 0° . (b) Frequency vs. aspect at 0° . (c) Time vs. aspect at 45° . (d) Frequency vs. aspect at 45° . (e) Time vs. aspect at 90° . (f) Frequency vs. aspect at 90° .*

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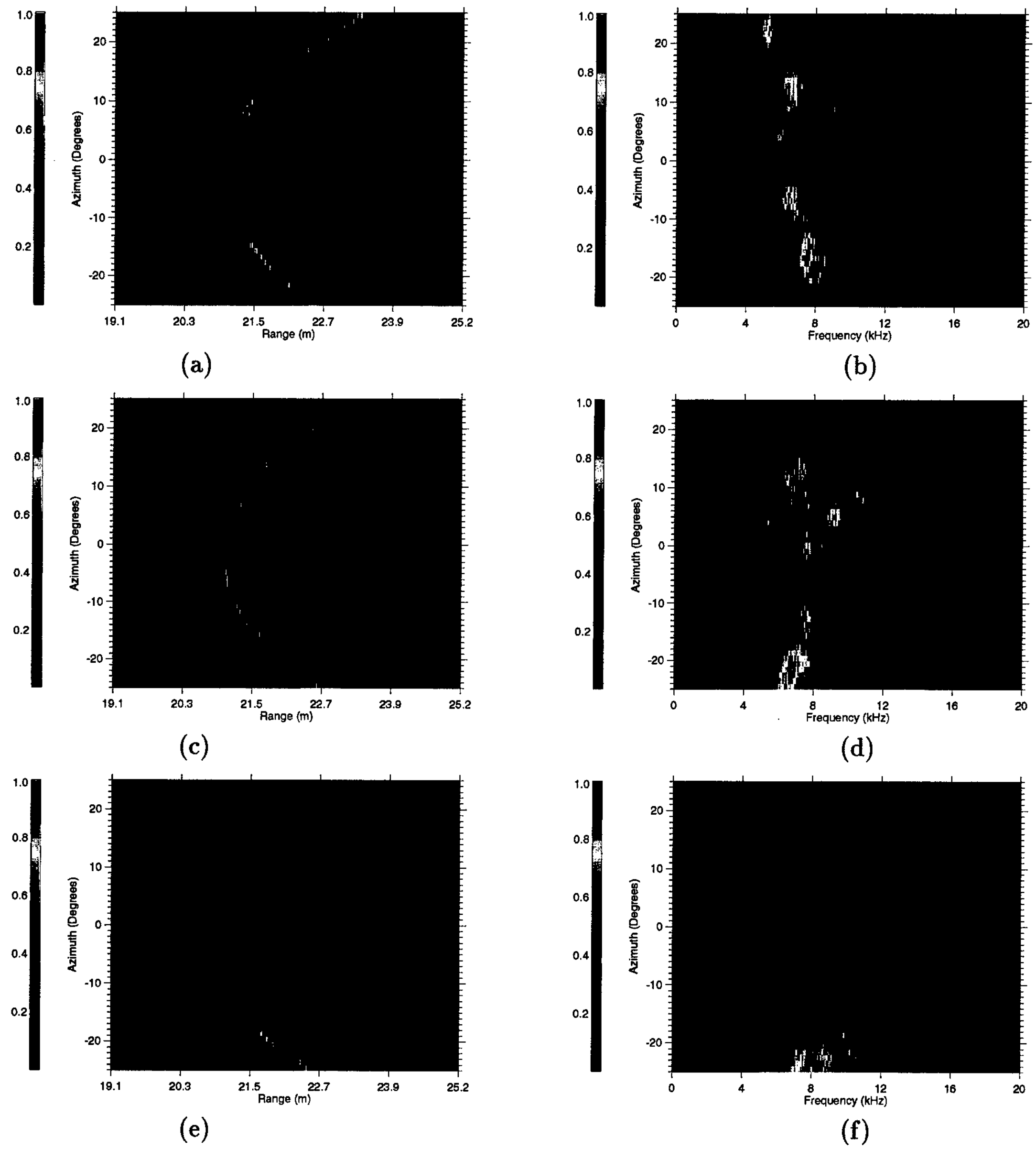


Figure 8 *Aspect variation of the scattered sound for the "Val-di-Pino" rock. In each plot, the amplitude is normalized to the maximum. (a) Time vs. aspect at* 0° *. (b) Frequency vs. aspect at* 0° *. (c) Time vs. aspect at* 45° *. (d) Frequency vs. aspect at* 45° *. (e) Time vs. aspect at* 90° *. (f) Frequency vs. aspect at* 90° *.*

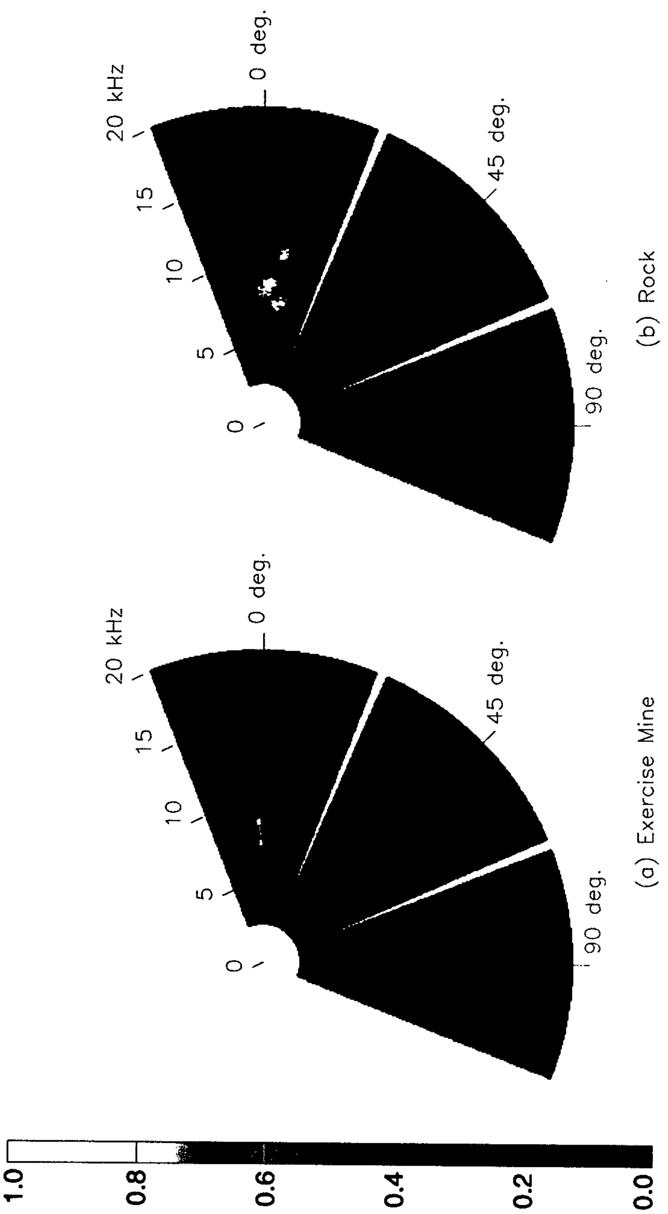


Figure 9 *Frequency versus aspect representation of the scattered sound of the rock and the exercise mine for 0°, 45° and 90° aspects*

3
Multiple aspect shadow classification

The difference between high and low frequency target signature can be emphasized by acquiring the same objects with two different acoustic sources. The TASCOE experiment provided the opportunity to use two different frequency bands: the 320-330 kHz band of the interferometric sonar and the 2-20 kHz secondary band of a parametric sonar.

The high-frequency images (Figs. 10 and 11) of the target are built by emulating a sector scan sonar. The pan device is used to rotate the transducer and the motion reference unit acquires the beam heading. The purpose of high frequency data processing is, first, to demonstrate the concept of multiple aspect classification [4] on real data and, second, to provide a basis of comparison between high and low frequency target acoustic signatures.

The shadow information is extracted from the images (Figs. 10 and 11). The height profiles (or target vertical cross section) are estimated using the shadow boundaries, the range to the target and the altitude of the sonar. The classification of each aspect is achieved by radial basis functions (RBF) of Gaussian shape [4, 8], and the fusion between aspects is based on evidential reasoning [9]. The combination of these two techniques has lead to successful results on satellite remote sensing images for wind front extraction and ship detection [10, 11].

The RBF are trained to recognize a 2 m cylinder, 50 cm ϕ. The RBF classification of the first view of the two objects (Figs. 10(a) and 11(a)) shows high probability of a cylinder seen at end-fire. The probability is 0.97 for the rock to be a cylinder at end-fire and 0.89 for the exercise mine. The lower probability for the exercise mine is due to the distortion of its shadow by the sand ripples. The classification of the second view (Figs. 10(b) and 11(b)) shows fairly high probability (0.76) to be a cylinder at 45° for the exercise mine. The rock has high probability (0.97) to be a cylinder at 0° but extremely low probability (0.01) to be a cylinder at 45°. The combination of the two views (0° and 45°) using Dempster-Shafer evidential reasoning gives probability of 0.95 to be a cylinder for the exercise mine. For the rock, the probability to be a cylinder falls down to 0.64. The classification of the third view (Figs. 10(c) and 11(c)) shows fairly high probability (0.64) to be a cylinder at 90° for the exercise mine. The rock has high probability (0.88) to be a cylinder at 0° but extremely low probability (0.04) to be a cylinder at 90° .When

combining three views (0° , 45° and 90°), the probability to be a cylinder is 0.97 for the exercise mine and 0.23 for the rock. Despite a fairly coarse resolution in azimuth[1], the discrimination between the rock and the exercise mine can be achieved using the shadows from 3 views (0° , 45° and 90°). As this classification method can be applied to existing operational mine hunting sonars, the results presented in this section can be used as reference results to better appreciate the information introduced by the low frequency echoes (Sect. 4 and 5).

[1]single element transducer, frequency 326 kHz, length ' 45 cm, no near field focusing.

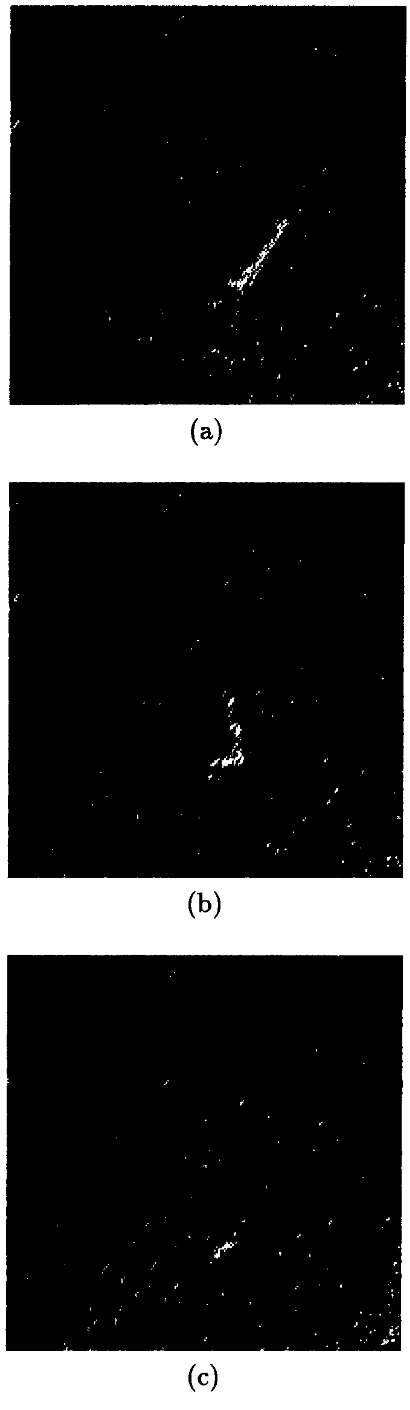
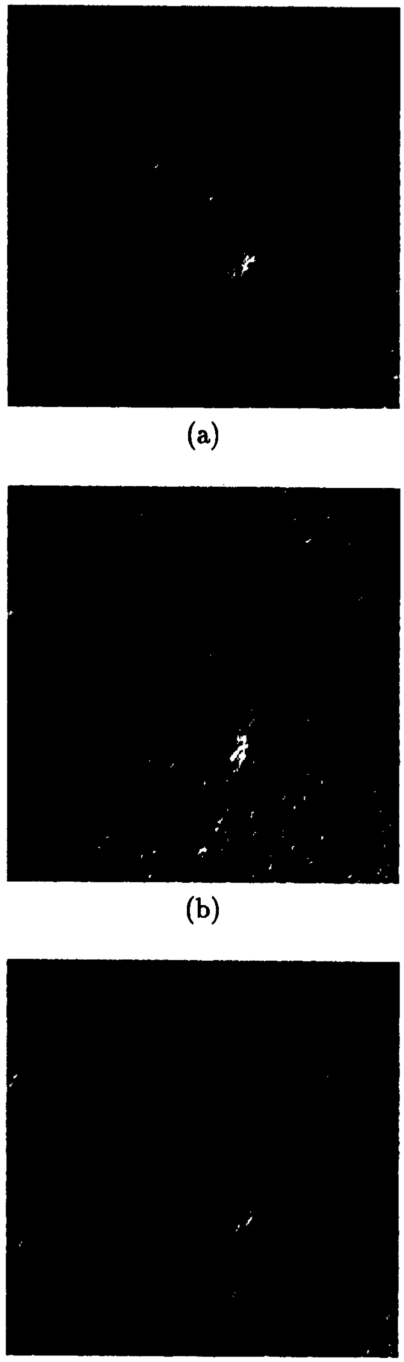


Figure 10 *High frequency image of the exercise mine for $0°$, $45°$ and $90°$ aspects.*



(a)

(b)

(c)

Figure 11 *High frequency image of the NRL rock for 0°, 45° and 90° aspects.*

4
Time vs. Aspect Processing : Reconstruction of the external shape

Tomographic reconstruction performed well on the free field data, with the object rotating and the transmitter-receiver at a fixed location [1, 2]. In the TASCOE experiment, the target was at a fixed location with aspect variation provided by changing the location of the tower on the rail. The variation of bathymetry modifies the tower inclination, so that consecutive locations of the sonar are not perfectly aligned. The successive positions of the sonar are estimated using genetic algorithms. The implementation of the genetic algorithms follows the approach used by Gerstoft to solve inversion problems [12]. Figure 12 shows the time vs aspects representation of the backscattered envelope before and after misalignment compensation for the exercise mine at 45°.

Considering that for each aspect the returned signal $g(s, \theta)$ contains the the wave reflected by the entire object, the reflection map $f_r(x, y)$ is reconstructed by back-projection:

$$f_r(x,y) = \int_0^{2\pi} g(x\cos\theta + y\sin\theta, \theta)\ d\theta \tag{1}$$

To meet the planar conditions required to apply the above 2D equation, the reconstruction of the reflection tomography should be performed with low grazing angle for a full 360° circumnavigation. On the TASCOE data, the performance of the tomographic reconstruction is limited by several experimental factors. The acquisition along the 20 m linear rail provides aspect variation of 45° (in azimuth) but the grazing angle cannot be kept low: its mean value is 16° and varies by about 2°. The reconstruction result is also limited by the partial acquisition in azimuth (180° instead of 360°). However, despite these limitations, the results obtained experimentally on the exercise mine and the rock (Fig. 13) allow to recognize the external shape of these objects. The dimensions estimated from the reconstructed shape will be used as input parameters for the multiple aspect resonance scattering analysis, described in the following section.

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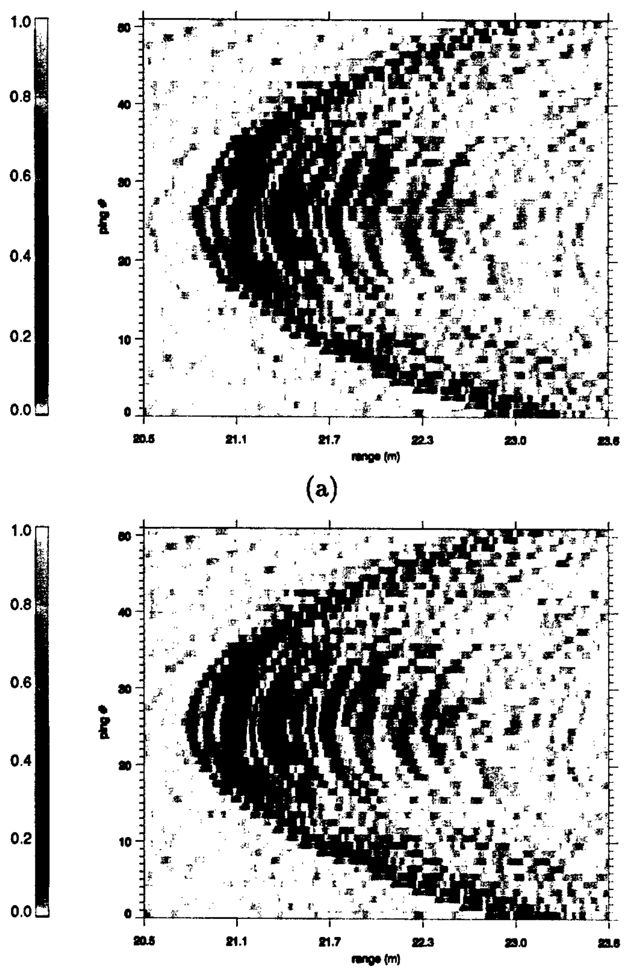

(b)

Figure 12 *Compensation of tower misalignment*

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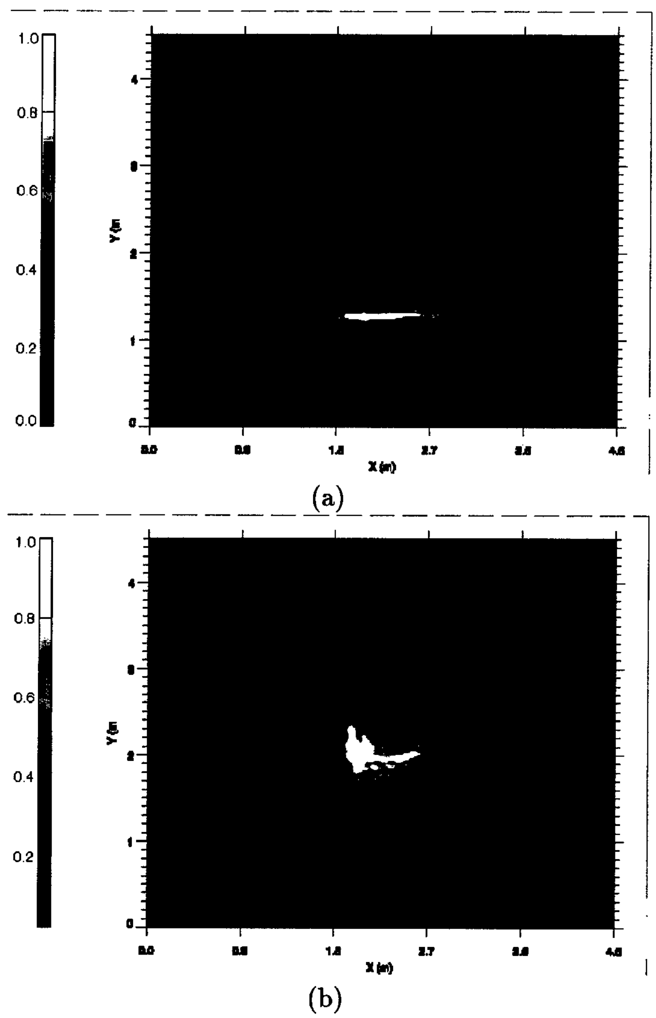

Figure 13 *Tomographic Reconstruction. Exercise mine (left). Rock(right)*

5

Frequency vs. Aspect Processing : Rigid and elastic scattering analysis

Previous works [1][2] have outlined the significant difference between a man-made and a natural target in the frequency-aspect domain. In [13][14] theoretical investigations have been focused on the rigid and elastic scattering effects of mine-like, fluid-(air and water) filled, thin-walled, cylindrical shells off-broadside. The theory has been validated by the analysis of at-sea measurements from either free-field or proud targets. In this report the basic concepts of the analysis is proposed again in order to select the main discriminating features which are expected to be common between a fluid-filled steel cylinder with flat ends and a fiber-glass cylindrical mine. Hence results obtained from quasi-canonical cylindrical shapes are extended to the roughly cylindrical exercise mine measured during the TASCOE experiment.

The reference case considered for modeling the behavior of rigid and elastic features from target multiple-aspect backscattering response is a flat-end cylindrical thin-walled steel shell in the free space [13][14][15] (see Fig. 14). From the target rigid response, two families of mode loci, the axial and radial modes, are generated from the interaction of diffraction at the corner (S) with the visible corners (A) and (R), respectively (Fig. 14a). In the frequency-aspect plane the mode loci follow quasi-hyperbolic curves centred at either broadside or endfire as shown in Fig. 15(a) where a set of modeled mode loci of the two types are superimposed on the rigid response of an air-filled steel cylinder with flat ends simulated by a FEM-BEM model [16]. The two families of diffraction features are related to cylinder length L and outer radius a respectively, as proved by the mathematical models in Table 1. Here, c_{out} is the outer sound speed around the target, α is the incident angle, n is the mode number.

According to the thin-shell theory off-broadside [17][18], the elastic response of a generic thin-walled shell at low to intermediate frequencies is mainly characterized by helical shell-borne waves (such as Lamb-type S_0, compressional P and shear S waves) and outer-fluid borne Scholte-Stoneley waves (Fig. 14b). If the shell is liquid-filled, also inner-fluid-borne surface waves and multiple internal bounces, characterized by helical paths around the shell, are generated [14][15]. The modal loci of these helical elastic waves follow quasi-parabolic curves centred at broadside as shown in Fig. 14(b) where a set of modeled curves of the Lamb-type and shear types are superimposed on the pure resonance response of an air-filled steel cylinder with flat

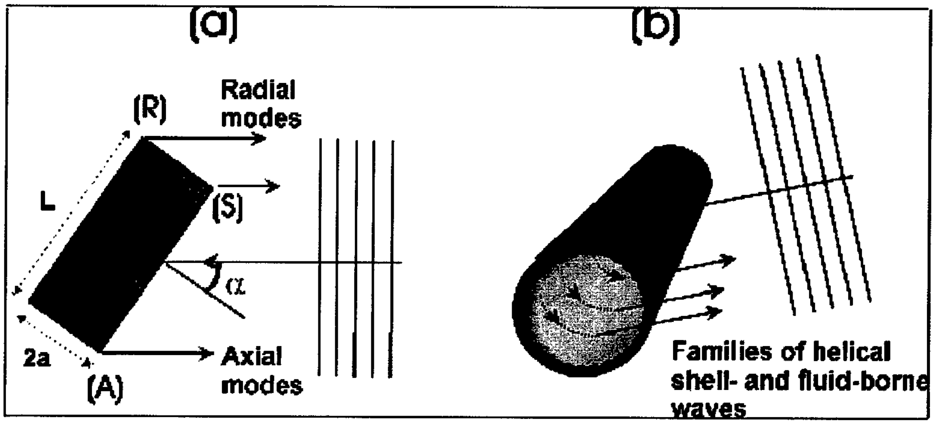

Figure 14 *Simplified scheme of the generation and travel path of the selected classes of rigid (a) and elastic (b) features*

ends simulated by the aforesaid FEM-BEM model [16]. The compressional mode loci are not distinguishable. These wave mode loci are parameterized by the target geometrical and elastic properties, as shown by the analytical models presented in Table 2. The table includes only those shell-borne waves that are expected to be generated and better identifiable in the case of a proud/buried partially solid-filled cylindrical mine. In the case of the exercise mine, the outer fluid-borne waves and the multiple internal bounces, which both characterize the response of a liquid-filled thin-walled cylinder of similar external shape and size [13][15] under the same experimental geometry, are expected to be either weak or totally missing.
The inversion of the models selected in Tables 1 and 2 allows estimation of target parameters, hence aids target identification. The target elastic and geometrical properties that are more significantly related to the selected phenomena through the indicated approximated formulas are the shell mean radius R (defined as the radius of the average shell cross-section), and the shell material membrane (c^*), compressional (c^p) and shear (c^s) sound speeds. The limited number and types of waves to detect, identify and analyze do not allow the estimation of shell thickness and filling, which has been proved to be feasible in the case of liquid-filled cylinders even when laying proud on the seabed [13][15].

The multiple aspect spectral representation of the cylindrical exercise mine shows diffraction (Fig. 16(a)) and elastic features (Fig. 16(b)). The diffraction and elastic features appear in the frequency-aspect domain as quasi-hyperbolic and quasi-parabolic curves centred at either broadside or endfire, producing regular, patterned textures, which are not evident in the response of natural objects.

The diffraction analysis of the mine in Fig. 16(a) is performed by superimposing axial/radial mode loci for a flat-end cylinder of the same size as the mine. In the case of a cylinder each axial mode locus would correspond to one dip curve of data,

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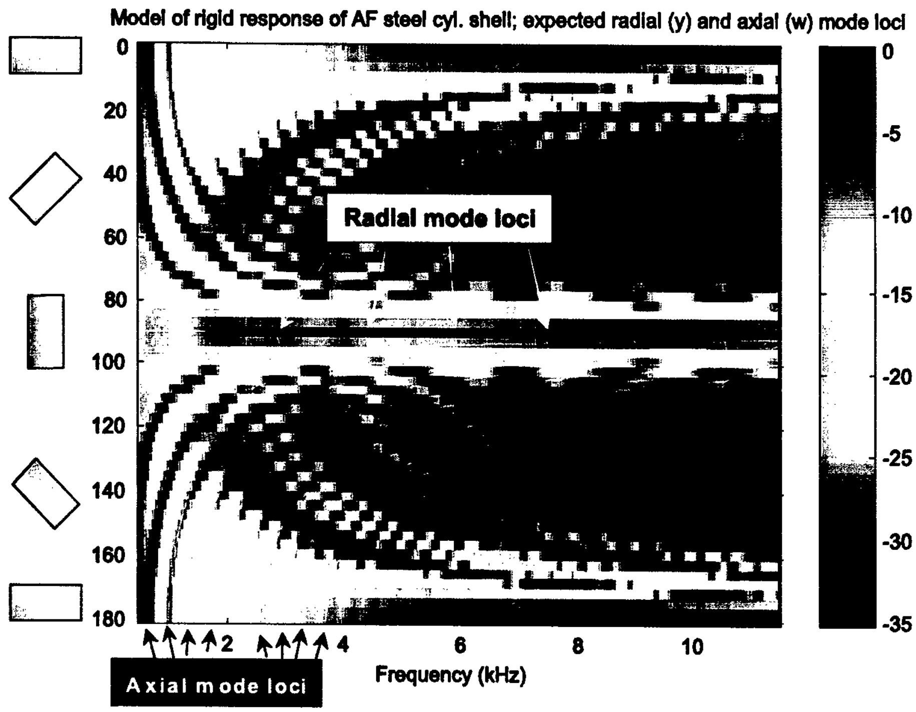
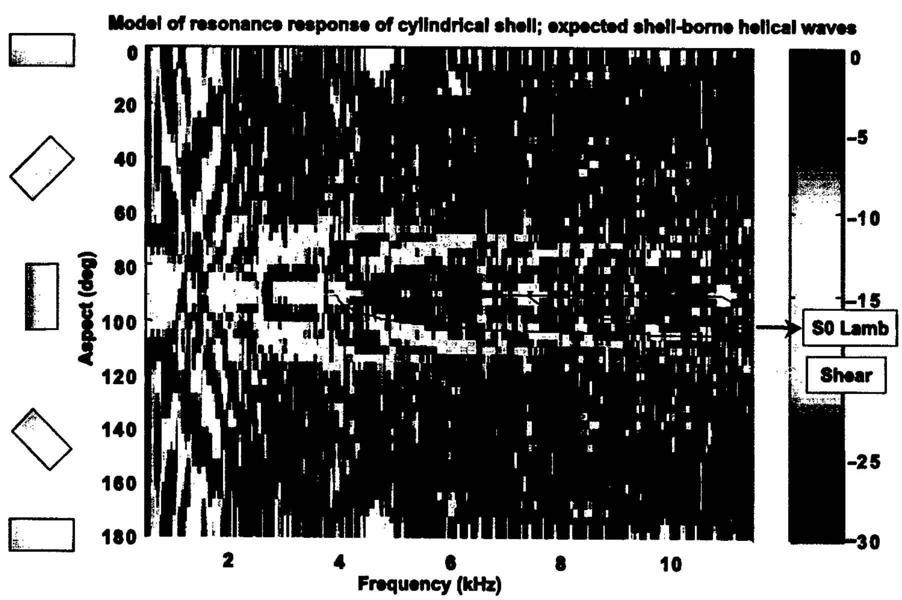
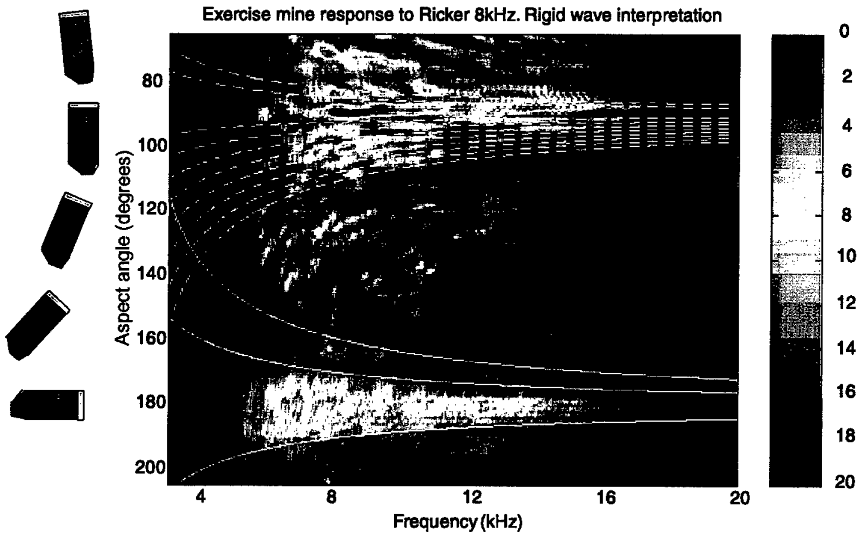


(a)

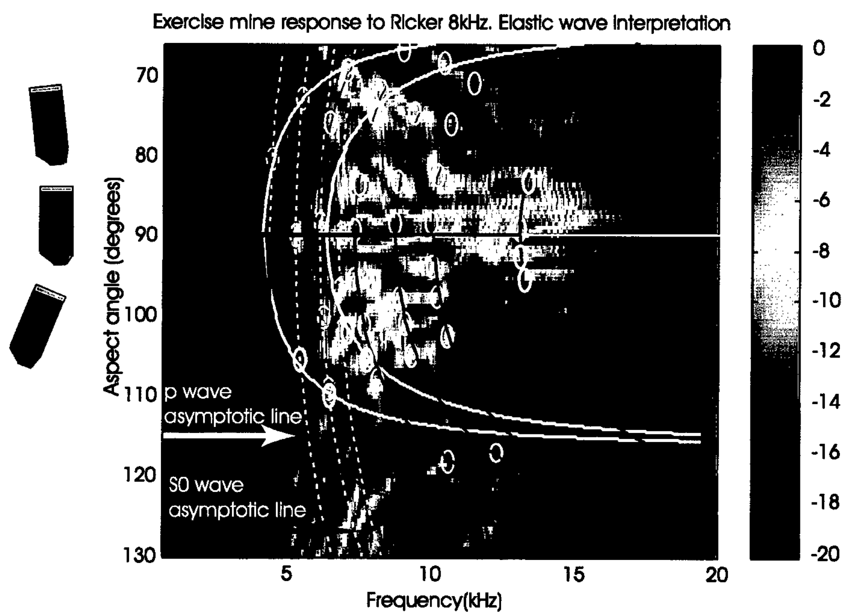


(b)

Figure 15 *Rigid and elastic feature identification on the simulated frequency-aspect backscattered response of a flat-end air-filled steel cylindrical shell in the free space.*



(a)



(b)

Figure 16 *Rigid and elastic feature identification of the exercise mine on the bottom. The broken lines in (a) correspond to the modelled axial mode loci, the solid lines to the radial mode loci. The preliminary analysis of elastic wave scattering in (b) (zoom of (a) around broadside) provides the identification of several mode loci of the S_0 Lamb-type wave (solid red curve) which were obtained by connecting energy peaks (outlined by circles) generated at the intersection of the elastic wave modes with the diffraction mode loci. Also some p and s wave mode loci are assumed (solid and broken white curves).*

whereas for the exercise mine, the modeled axial mode loci overlap alternatively dip and peak curves of the response. This effect might derive from the shape of the target, which has one flat endcap and one partially oblique endcap. The resulting smoother shape of this latter endcap should give rise to a more limited diffraction effect. According to this interpretation, the resulting diffraction pattern characterizes this exercise mine type and can be considered part of its signature.

The preliminary analysis of resonance scattering contributions provides the identification of several wave modes (see Fig. 16(b)).
The class of shell material (fiber glass) and the partial solid filling of the target make the extraction and identification of the the elastic waves much more difficult and less robust than in the case of a fluid-filled metal shell of the same size.
Indeed only a set of peaks generated by the interaction of the selected elastic wave modes with the diffraction mode loci are evident in the frequency-aspect plane (see Fig. 16(b) where these peaks are outlined by cycles). From their detection, the elastic wave mode loci have been obtained by connecting these peaks. The identification of S_0 wave mode loci (solid red curves) is the most robust. Also some compressional p (solid white lines) and shear s (broken white lines) wave mode loci are assumed. Further, the fiber-glass is an anysotropic material with assumed values of compressional and shear speeds of about 3440 and 1360 m/s respectively (hence with a membrane speed of 2500 m/s roughly). These particularly low values of material speeds (in particular the shear one) make one assume that the asymptotic lines for the S_0 wave modes are located at azimuth angles far away broadside (i.e., around 37°), where they cannot be distinguished as the signal level decreases significantly.

Diffraction features	Target parameters	Matching model	Applicable to
Axial modes f_n^{ax}	L	$L = n\frac{c_{out}}{2f_n^{ax}\sin\alpha}$	any cylinder with flat endcaps
Radial modes f_n^{Rad}	A	$a = n\frac{c_{out}}{4f_n^{Rad}\cos\alpha}$	any cylinder with flat endcaps

Table 1 *Proposed matching models for diffraction features*

Elastic waves	Target parameters	Matching model model	Applicable to
Lamb S_0 wave f_n^{S0}	$R = \frac{(a+b)}{2}$, c^*	$\left(\frac{c^*\sin\alpha}{c_{out}}\right)^2 = 1 - (\frac{nc^*}{2\pi f_n^{S0}R})^2$	any thin-walled cylindrical shell
P wave f_n^P	R, c^p	$\left(\frac{c^p\sin\alpha}{c_{out}}\right)^2 = 1 - (\frac{nc^p}{2\pi f_n^P R})^2$	any thin-walled cylinder shell
S wave f_n^S	R, c^s	$\left(\frac{c^s\sin\alpha}{c_{out}}\right)^2 = 1 - (\frac{nc^s}{2\pi f_n^S R})^2$	any thin-walled cylinder shell

Table 2 *Proposed matching models from thin shell theory for elastic features.*

6
Conclusions

A classification/identification technique is described based on multiple-aspect target echo analysis in the time and the frequency domains, which considers the rigid response (returned by any kind of target) and the so-called resonance response (in the case of man made objects having particular symmetries). This method could be used to complement current classification techniques for classifying proud targets which have similar external shapes or as a main classification tool when current techniques fail (e.g., for buried targets). Future work will be dedicated to the validation of the results presented here on more complex cases (different bottom type, different targets) through modelling and at-sea experiments, in order to be able to specify a system design for the detection and the classification of buried mines. Further, automatic procedures of feature extraction and identification in multi-aspect scattering analysis will be investigated.

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Title

Proud target classification based on multiple aspect low frequency response.

Abstract

The aspect dependence of the acoustic signature has been demonstrated to be an essential indicator to discriminate between man made and natural underwater objects. A classification method has been defined using the variation with incidence angle of the acoustic waves scattered by an elastic object. As the experiment conducted in a basin on free field cylinders has given encouraging results, more realistic acoustic measurements have been conducted on natural and manufactured objects positioned on the seabed. The external shape, extracted from its reflection map reconstructed by tomography, allows selection of candidate objects for detailed analysis of their scattering properties. The resonance scattering analysis, limited to selected aspects in its original version (e.g. broadside for a cylindrical shape) has been extended to incorporate aspect varying features. The variation with incidence of the acoustic wave diffracted by object discontinuities has also been introduced. This paper reviews the classification technique and describes the SACLANTCEN-NRL TASCOE (TArget Scattering in COntrolled Environment) experiment conducted in water depth of 15 m at Marciana Marina (Elba, Italy) in October 98. The results obtained from the data analyzed show that the aspect dependence of the acoustic waves scattered by elastic objects (ka 2-20) allows clear discrimination between manufactured and natural objects.

Keywords

Sea mine classification – automatic target classification – resonance scattering analysis – computerized tomography

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